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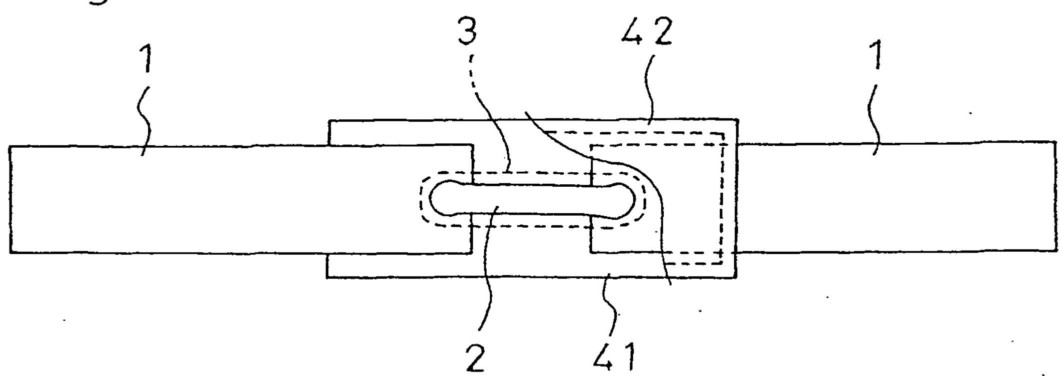
(54) Alloy type thermal fuse and fuse element thereof

(57) The invention provides a thermal fuse and a fuse element of the low-melting fusible alloy type in which the fuse element has an alloy composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and a total of 0.01 to 7 weight parts of at least one selected from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of the composition. As a result, the operating temperature is in the range of 57 to 67°C, requests for environment conservation can be satisfied, the diameter of the fuse element can be made very thin or reduced to about 300 μmϕ, self-heating can be suppressed, and the thermal stability can be satisfactorily guaranteed.

Fig. 1



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Description

Field of the Invention

[0001] The present invention relates to an alloy type thermal fuse, more particularly to improvement in an alloy type thermal fuse of an operating temperature of 57 to 67°C, and also to a fuse element which constitutes such a fuse, and which is made of a low-melting fusible alloy.

Description of Related Art

[0002] In a conventional alloy type thermal fuse, a low-melting fusible alloy piece to which a flux is applied is used as a fuse element. Such a thermal fuse is mounted on an electric apparatus to be protected. When the electric apparatus abnormally generates heat, a phenomenon occurs in which the low-melting fusible alloy piece is liquefied by the generated heat, the molten metal is spheroidized by the surface tension under the coexistence with the flux that has already melted, and the alloy piece is finally broken as a result of advancement of the spheroidization, whereby the power supply to the apparatus is interrupted.

[0003] The first requirement which is imposed on such a low-melting fusible alloy is that the solid-liquid coexisting region between the solidus and liquidus lines is narrow. In an alloy, usually, a solid-liquid coexisting region exists between the solidus and liquidus lines. In this region, solid-phase particles are dispersed in a liquid phase, so that the region has also the property similar to that of a liquid phase, and therefore the above-mentioned breakage due to spheroidization may occur. As a result, there is the possibility that a low-melting fusible alloy piece is spheroidized and broken in a temperature range (indicated by ΔT) which is lower than the liquidus temperature (indicated by T), and which belongs to the solid-liquid coexisting region. Therefore, a thermal fuse in which such a low-melting fusible alloy piece is used must be handled as a fuse which operates at a fuse element temperature in a range of $(T - \Delta T)$ to T. As ΔT is smaller, or as the solid-liquid coexisting region is narrower, the operating temperature of a thermal fuse is less dispersed, so that a thermal fuse can operate at a predetermined temperature in a correspondingly strict manner. Therefore, an alloy which is to be used as a fuse element of a thermal fuse is requested to have a narrow solid-liquid coexisting region.

[0004] The second requirement which is imposed on such a low-melting fusible alloy is that the electrical resistance is low. When the temperature rise by normal heat generation due to the resistance of the low-melting fusible alloy piece is indicated by $\Delta T'$, the operating temperature is substantially lower by $\Delta T'$ than that in the case where such a temperature rise does not occur. Namely, as $\Delta T'$ is larger, the operation error is substantially larger. Therefore, an alloy which is to be used as a fuse element of a thermal fuse is requested to have a low specific resistance.

[0005] A thermal fuse is repeatedly heated and cooled by heat cycles of an apparatus. During the heat cycles, re-crystalization of a fuse element is promoted. When the ductility of the fuse element is excessively large, larger distortion (slip) occurs in the interface between different phases in the alloy structure. When the distortion is repeated, a change in sectional area and an increase of the length of the fuse element are extremely caused. As a result, the resistance of the fuse element itself becomes unstable, and the thermal stability cannot be guaranteed. Therefore, also the thermal stability must be emphasized as a further requirement which is imposed on such a low-melting fusible alloy.

[0006] In order to severely manage an apparatus, recently, thermal fuses of an operating temperature of about 60°C are requested. In a fuse element of such a thermal fuse, it is necessary that the solid-liquid coexisting region is in the vicinity of 60°C, and the above-mentioned ΔT (the temperature range belonging to the solid-liquid coexisting region) must be within an allowable range (not larger than 4°C). As a low-melting fusible alloy of such a melting point, for example, known are, for example, an In-Bi-Cd alloy (61.7% In, 30.8% Bi, and 7.5% Cd (% means a weight percent (the same is applicable in the following description))) which is eutectic at 62°C, an In-Bi-Sn alloy (51% In, 32.5% Bi, and 16.5% Sn) which is eutectic at 60°C, and a Bi-In-Pb-Sn alloy (49% Bi, 21% In, 18% Pb, and 12% Sn) which is eutectic at 58°C.

[0007] However, the In-Bi-Cd alloy which is eutectic at 62°C is not suitable to environment conservation which is a recent global request, because, among Pb, Cd, Hg, and Tl which are seemed to be harmful to the ecological system, Cd is contained in the alloy. In the alloy, In which is high in ductility occupies the majority of the composition, and hence the elastic limit is small. Therefore, the fuse element is caused to yield by thermal stress due to heat cycles, and a slip occurs in the alloy structure. As a result of repetition of such a slip, the sectional area and the length of the fuse element are changed, so that the resistance of the element itself is unstable and the thermal stability cannot be guaranteed.

[0008] The Bi-In-Pb-Sn alloy which is eutectic at 58°C is not suitable to environment conservation which is a recent global request, because Pb which is a metal harmful to the ecological system is contained in the alloy. The alloy contains a large amount of Bi, and therefore is so fragile that a process of drawing the alloy into a very thin wire of 300 μmϕ is hardly performed. Therefore, the alloy can hardly cope with the miniaturization of an alloy type thermal fuse which is conducted in accordance with the recent tendency that electric or electronic apparatuses are further reduced in size. In such a very thin fuse element, moreover, the relatively high specific resistance of the alloy composition cooperates

with the thinness to extremely raise the resistance, with the result that an operation failure due to self-heating of the fuse element inevitably occurs.

[0009] In the In-Bi-Sn alloy which is eutectic at 60°C, no harmful metal is contained, a process of drawing the alloy into a very thin wire of 300 μmϕ can be performed, and the specific resistance is low. In the same manner as the In-Bi-Cd alloy which is eutectic at 62°C, however, In which is high in ductility occupies the majority of the composition, and hence the elastic limit is small. Therefore, the fuse element is caused to yield by thermal stress due to heat cycles, and a slip occurs in the alloy structure. As a result of repetition of such a slip, the sectional area and the length of the fuse element are changed, so that the resistance of the element itself is unstable and the thermal stability cannot be guaranteed.

[0010] It is an object of the invention to provide an alloy type thermal fuse in which an alloy composition of In-Sn-Bi is used as a fuse element, the operating temperature is in the range of 57 to 67°C, requests for environment conservation can be satisfied, the diameter of the fuse element can be made very thin or reduced to about 300 μmϕ, self-heating can be sufficiently suppressed, and the thermal stability can be satisfactorily guaranteed.

Summary of the Invention

[0011] In one embodiment of the present invention, the alloy type thermal fuse is a thermal fuse in which a low-melting fusible alloy is used as a fuse element, wherein the low-melting fusible alloy has an alloy composition in which a total of 0.01 to 7 weight parts of at least one selected from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and balance Bi.

[0012] In the above fuse, the alloy composition is allowed to contain inevitable impurities which are produced in productions of metals of raw materials and also in melting and stirring of the raw materials.

Brief Description of the Drawings

[0013]

Fig. 1 is a view showing an example of the alloy type thermal fuse of the invention;
Fig. 2 is a view showing another example of the alloy type thermal fuse of the invention;
Fig. 3 is a view showing a further example of the alloy type thermal fuse of the invention;
Fig. 4 is a view showing a still further example of the alloy type thermal fuse of the invention; and
Fig. 5 is a view showing a still further example of the alloy type thermal fuse of the invention.

Detailed Description of the Preferred Embodiments

[0014] In the alloy type thermal fuse of the invention, a circular wire having an outer diameter of 200 to 600 μmϕ, preferably, 250 to 350 μmϕ, or a flat wire having the same sectional area as that of the circular wire may be used as a fuse element.

[0015] The fuse element is made of an alloy having a composition in which a total of 0.01 to 7 weight parts of at least one selected from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi. The alloy has a single melting peak, and a sharp melting point of 57 to 67°C. Moreover, a solid phase transformation point at a low temperature is not generated, and an erroneous operation due to solid phase transformation breakage at a temperature which is lower than the operating temperature can be surely eliminated.

[0016] In the thermal fuse of the invention, the fuse element is configured as follows:

(1) In-Sn-Bi containing no metal harmful to environment conservation is used;
(2) the fuse element has a melting point by which the operating temperature can be set to 57 to 67°C, and the width ΔT of the solid-liquid coexisting region is suppressed to about 4°C at the maximum in order to sufficiently reduce dispersion of the above-mentioned operating temperature range;
(3) drawing into a very thin wire of about 300 μmϕ is enabled;
(4) the fuse element has a basic alloy composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, in order to sufficiently lower the resistance and suppress an operation error due to Joule's heat; and
(5) a total of 0.01 to 7 weight parts of at least one selected from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of the base composition, in order that an intermetallic compound with In of large ductility is produced and the thermal stability against the above-mentioned heat cycles is enhanced by a wedge effect in which an intercrystalline slip is prevented from occurring by the intermetallic compound.

The reason why the total addition amount of at least one of Au, Ag, Cu, Ni, and Pd is set to 0.01 to 7 weight parts is because, when the addition amount is smaller than 0.01 weight parts, (5) above is hardly attained, and, when the amount is larger than 7 weight parts, (2) and (3) above cannot be satisfactorily attained.

[0017] The fuse element of the thermal fuse of the invention can be produced by drawing a base material of an alloy, and used with remaining to have a circular shape or with being further subjected to a compression process to be flattened.

[0018] Fig. 1 shows a tape-like alloy type thermal fuse according to the invention. In the fuse, strip lead conductors 1 having a thickness of 100 to 200 μm is fixed by an adhesive agent or fusion bonding to a plastic base film 41 having a thickness of 100 to 300 μm. A fuse element 2 having a diameter of 250 to 500 μmϕ) is connected between the strip lead conductors. A flux 3 is applied to the fuse element 2. The flux-applied fuse element is sealed by means of fixation of a plastic cover film 42 having a thickness of 100 to 300 μm by an adhesive agent or fusion bonding.

[0019] The alloy type thermal fuse of the invention may be realized in the form of a fuse of the case type, the substrate type, or the resin dipping type.

Fig. 2 shows a fuse of the cylindrical case type. A low-melting fusible alloy piece 2 is connected between a pair of lead wires 1, and a flux 3 is applied onto the low-melting fusible alloy piece 2. The flux-applied low-melting fusible alloy piece is passed through an insulating tube 4 which is excellent in heat resistance and thermal conductivity, for example, a ceramic tube. Gaps between the ends of the insulating tube 4 and the lead wires 1 are sealingly closed by a cold-setting adhesive agent 5 such as an epoxy resin.

[0020] Fig. 3 shows a fuse of the radial case type. A fuse element 2 is bonded between tip ends of parallel lead conductors 1 by welding. and a flux 3 is applied to the fuse element 2. The flux-applied fuse element is enclosed by an insulating case 4 in which one end is opened, for example. a ceramic case. The opening of the insulating case 4 is sealingly closed by a sealing agent 5 such as an epoxy resin.

[0021] Fig. 4 shows a fuse of the substrate type. A pair of film electrodes 1 are formed on an insulating substrate 4 such as a ceramic substrate by printing of conductive paste (for example, silver paste). Lead conductors 11 are connected respectively to the electrodes 1 by welding or the like. A fuse element 2 is bonded between the electrodes 1 by welding, and a flux 3 is applied to the fuse element 2. The flux-applied fuse element is covered by a sealing agent 5 such as an epoxy resin.

[0022] Fig. 5 shows a fuse of the radial resin dipping type. A fuse element 2 is bonded between tip ends of parallel lead conductors 1 by welding, and a flux 3 is applied to the fuse element 2. The flux-applied fuse element is dipped into a resin solution to seal the element by an insulative sealing agent 5 such as an epoxy resin.

[0023] The invention may be realized in the form of a fuse having an electric heating element, such as a substrate type fuse having a resistor in which, for example, a resistor (film resistor) is additionally disposed on an insulating substrate of an alloy type thermal fuse of the substrate type, and, when an apparatus is in an abnormal state, the resistor is energized to generate heat so that a low-melting fusible alloy piece is blown out by the generated heat.

[0024] As the flux, a flux having a melting point which is lower than that of the fuse element is generally used. For example, useful is a flux containing 90 to 60 weight parts of rosin, 10 to 40 weight parts of stearic acid, and 0 to 3 weight parts of an activating agent. In this case, as the rosin, a natural rosin, a modified rosin (for example, a hydrogenated rosin, an inhomogeneous rosin, or a polymerized rosin) , or a purified rosin thereof can be used. As the activating agent, hydrochloride of diethylamine, hydrobromide of diethylamine, or the like can be used.

[0025] Now, embodiments of the present invention will be described in greater detail by way of example, wherein 50 specimens of the substrate type were used in measurements of the operating temperatures of Examples and Comparative Examples which will be described later, each of the specimens was immersed into an oil bath in which the temperature was raised at a rate of 1°C/min., while supplying a current of 0.1 A to the specimen, and the temperature of the oil when the current supply was interrupted by blowing-out was measured. With respect to the influence of self-heating, 50 specimens were used, and judgment was made while supplying a usual rated current (1 to 2 A) to each specimen.

With respect to the change in resistance of a fuse element caused by heat cycles, 50 specimens were used, and judgment was made by measuring a resistance change after a test of 500 heat cycles in each of which specimens were heated to 50°C for 30 minutes and cooled to -40°C for 30 minutes.

Example (1)

[0026] A base material of an alloy composition of 53% In, 28% Bi, 18% Sn, and 1% Au was drawn into a wire of 300 μmϕ) in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred.

The specific resistance of the wire was measured. As a result, the specific resistance was 29 μΩ•cm. The wire was cut into pieces of 4 mm, and small substrate type thermal fuses were produced with using the pieces as fuse elements. A composition of 80 weight parts of rosin, 20 weight parts of stearic acid, and 1 weight part of hydrobromide of diethylamine was used as a flux. A cold-setting epoxy resin was used as a covering member.

The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 60°C ± 2°C. It was confirmed that, under the usual rated current, no influence of self-heating is made. Furthermore, a change in resistance of the fuse element which was caused by the heat cycles, and which may become a serious problem was not observed. The specimens exhibited stable heat resistance.

It was confirmed that, in a range of 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and 0.01 to 7 weight parts of Au, the

thin wire drawability, the low specific resistance, and the thermal stability which have been described above can be sufficiently attained, and the operating temperature can be set to be within a range of 61°C ± 3°C.

Example (2)

[0027] A base material of an alloy composition of 52% In, 27% Bi, 18% Sn, and 3% Ag was drawn into a wire of 300 μmϕ) in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred. The specific resistance of the wire was measured. As a result, the specific resistance was 26 μΩ•cm.

The wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1).

The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 61°C ± 1°C. It was confirmed that, under the usual rated current, no influence of self-heating is made. Furthermore, a change in resistance of the fuse element which was caused by the heat cycles, and which may become a serious problem was not observed.

It was confirmed that, in a range of 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and 0.01 to 7 weight parts of Ag, the thin wire drawability, the low specific resistance, and the thermal stability which have been described above can be sufficiently attained, and the operating temperature can be set to be within a range of 61°C ± 3°C.

Example (3)

[0028] A base material of an alloy composition of 52% In, 28% Bi, 18% Sn, and 2% Cu was drawn into a wire of 300 μmϕ) in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred.

The specific resistance of the wire was measured. As a result, the specific resistance was 28 μΩ•cm The wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1).

The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 62°C ± 1°C. It was confirmed that, under the usual rated current, no influence of self-heating is made.

Furthermore, a change in resistance of the fuse element which was caused by the heat cycles, and which may become a serious problem was not observed.

It was confirmed that, in a range of 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and 0.01 to 7 weight parts of Cu, the thin wire drawability, the low specific resistance, and the thermal stability which have been described above can be sufficiently attained, and the operating temperature can be set to be within a range of 62°C ± 5°C.

Example (4)

[0029] A base material of an alloy composition of 52% In, 28% Bi, 18% Sn, 0.1% Ni, and 1.9% Cu was drawn into a wire of 300 μmϕ) in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred. The specific resistance of the wire was measured. As a result, the specific resistance was 26 μΩ•cm.

The wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1).

The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 61°C ± 1°C. It was confirmed that, under the usual rated current, no influence of self-heating is made.

Furthermore, a change in resistance of the fuse element which was caused by the heat cycles, and which may become a serious problem was not observed.

It was confirmed that, in a range of 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and 0.01 to 7 weight parts of a total of Cu and Ni, the thin wire drawability, the low specific resistance, and the thermal stability which have been described above can be sufficiently attained, and the operating temperature can be set to be within a range of 62°C ± 4°C.

Example (5)

[0030] A base material of an alloy composition of 52% In, 28% Bi, 18% Sn, 0.3% Pd, and 1.7% Cu was drawn into a wire of 300 μmϕ in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred. The specific resistance of the wire was measured. As a result, the specific resistance was 27 μΩ•cm.

The wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1).

The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 61°C ± 1°C. It was confirmed that, under the usual rated current, no influence of self-heating is made.

Furthermore, a change in resistance of the fuse element which was caused by the heat cycles, and which may become a serious problem was not observed.

It was confirmed that, in a range of 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and the balance Bi, and 0.01 to 7 weight parts of a total of Pd and Cu, the thin wire drawability, the low specific resistance, and the thermal stability which have been described above can be sufficiently attained, and the operating temperature can be set to be within a range of 62°C ± 5°C.

Comparative Example (1)

[0031] A base material of an alloy composition of 54% In, 28% Bi, and 18% Sn was drawn into a wire of 300 μmϕ in diameter. The draw-down ratio per dice was 6.5%, and the drawing speed was 45 m/min. In the wire, no breakage occurred. The specific resistance of the wire was measured. As a result, the specific resistance was 31 μΩ•cm.

The wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1). The operating temperatures of the resulting specimens were measured. The resulting operating temperatures were within a range of 61°C ± 1°C. It was confirmed that, under the usual rated current, no influence of self-heating is made. After a heat resistance test of 500 heat cycles, however, a large change in resistance occurred in some of the specimens. Such specimens were disassembled, and the fuse elements were observed. As a result, it was confirmed that the sectional areas of the fuse elements are partly reduced, and the lengths of the elements are elongated. The reason of this is seemed as follows. Since such a fuse element contains a large amount of In, the elastic limit is small. Therefore, the fuse element is caused to yield by thermal stress, and a slip occurs in the alloy structure. As a result of repetition of such a slip, the sectional area and the length of the fuse element are changed, so that the resistance of the element itself is varied.

This comparative example corresponds to Examples in which the addition amount of Au, Ag, Cu, Ni, Pd, or the like is zero. It can be confirmed that, in the invention, Au, Ag, Cu, Ni, Pd, and the like are effective in improving the thermal stability.

Comparative Example (2)

[0032] In the same manner as Examples, wire drawing into a wire of 300 μmϕ in diameter was attempted with using a base material of an alloy composition of 49% Bi, 21% In, 18% Pb, and 12% Sn. However, wire breakage frequently occurred. Therefore, the draw-down ratio per dice was reduced to 5.0%, and the drawing speed was lowered to 20 m/min. Under these conditions of reduced process strain, wire drawing was attempted. However, wire breakage frequently occurred, and it was impossible to perform drawing.

Since a thin wire process by drawing is substantially impossible as described above, a thin wire of 300 μmϕ in diameter was obtained by the rotary drum spinning method. The specific resistance of the thin wire was measured. As a result, the specific resistance was 61 μΩ•cm.

The thin wire was cut into pieces of 4 mm, and substrate type thermal fuses were produced with using the pieces as fuse elements in the same manner as Example (1). The operating temperatures of the resulting specimens were measured. As a result, it was confirmed that many specimens did not operate even when the temperature was largely higher than the melting point (58°C).

The reason of the above is seemed as follows. Because of the rotary drum spinning method, a thick sheath of an oxide film is formed on the surface of a fuse element, and, even when the alloy inside the sheath melts, the sheath does not melt and hence the fuse element is not broken.

[0033] The advantages of the present invention are as follows:

According to the invention, it is possible to provide an alloy type thermal fuse which uses a very thin fuse element of a diameter on the order of 300 μmϕ) obtained by an easy process of drawing the base material of a Bi-In-Sn low-melting fusible alloy that is harmless to the ecological system, and in which the operating temperature is 57 to 67°C, an operation error due to self-heating can be sufficiently prevented from occurring, and excellent thermal stability can be guaranteed because of the intercrystalline slip preventing effect (wedge effect) due to an intermetallic compound of In and Au, Ag, Cu, Ni, Pd, or the like.

Claims

1. An alloy type thermal fuse comprising a fuse element which has an alloy composition containing In, Sn, and Bi, **characterized in that** said alloy composition is a composition in which a total of 0.01 to 7 weight parts of at least one selected from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and balance Bi.

2. An alloy type thermal fuse according to claim 1, wherein said alloy composition contains inevitable impurities.

3. An alloy type thermal fuse according to claim 1 or 2, wherein an operating temperature is 57 to 67°C.

4. A fuse element constituting an alloy type thermal fuse, said fuse element having an alloy composition containing In, Sn, and Bi, **characterized in that** said alloy composition is a composition in which a total of 0.01 to 7 weight parts of at least one selected

from the group consisting of Au, Ag, Cu, Ni, and Pd is added to 100 weight parts of a composition of 48 to 60% In, 10 to 25% Sn, and balance Bi.

5. A fuse element according to claim 4, wherein said alloy composition contains inevitable impurities.

6. A fuse element according to claim 4 or 5, wherein an operating temperature is 57 to 67°C.

Fig. 1

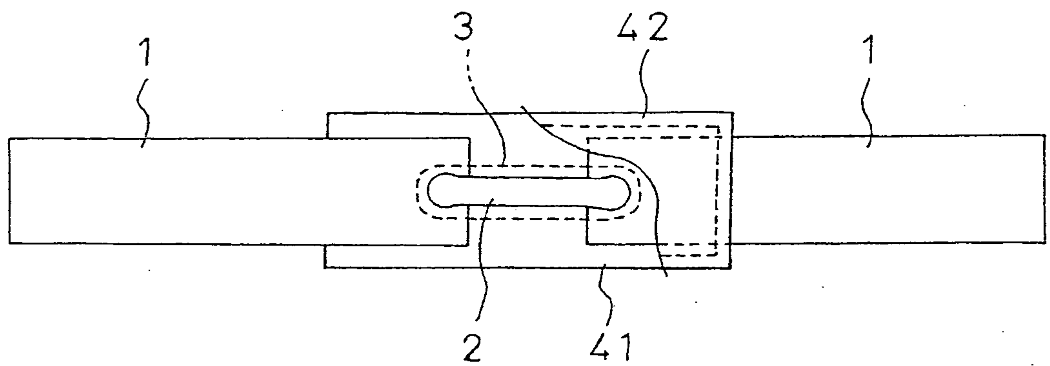

Fig. 2

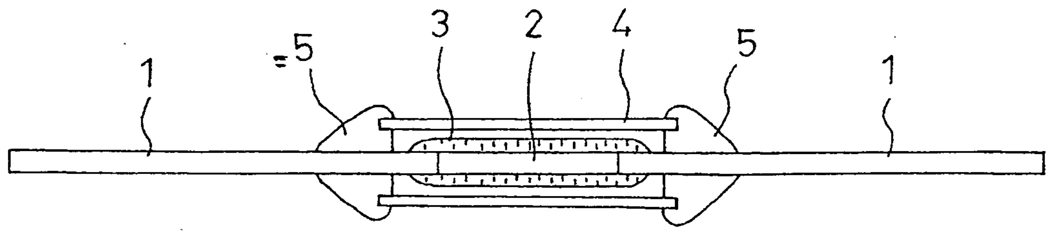

Fig. 3

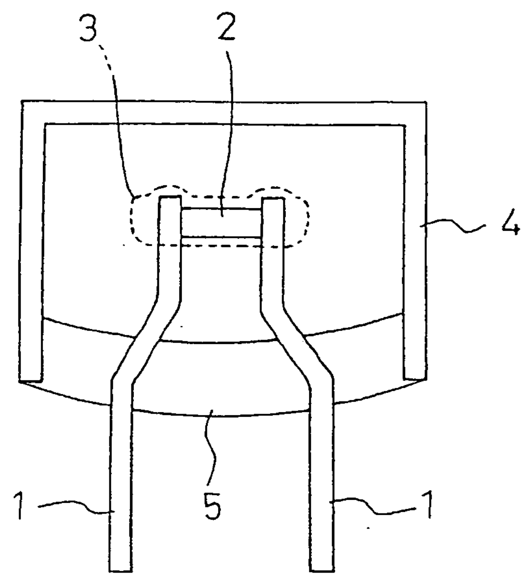

Fig. 4

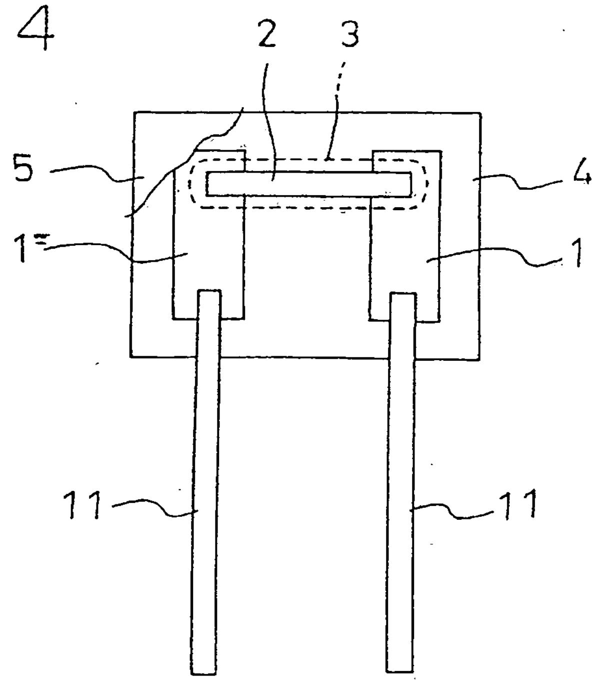

Fig. 5